THE HIGHWAY ROAD PAINTING POLICY FOR REDUCTION OF CO_2 WITH FUEL-CUT FUNCTION IN DOWNHILL PART OF HIGHWAY

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ABSTRACT

The fuel is not injected when the driver doesn't push acceleration pedal of a vehicle with engine speed higher than about 1,500rpm in mid speed range. This is called "fuel-cut function" and almost every modern vehicle is equipped with this function. This is activated on downhill part of a highway most often. Therefore the vehicle-exhausted CO_2 can be zero in this downhill part if the driver could recognize this part of highway. We compared the vehicle-exhausted CO_2 emission when using fuel-cut function with the CO_2 emission when without using this function in this study. We found that the CO_2 emission reduced with fuel-cut function and measured the reduction rate of vehicle-exhausted CO_2 mass with this test results. The exhausted CO_2 mass of a passenger car(2,000cc engine volume) is reduced by 4% with this function used. This CO_2 reduction effect can be achieved if the downhill part of a highway is painted with a specific color. And this road painting can be included in the highway road rehabilitation policy.

1. INTRODUCTION

The fuel is not injected when the driver doesn't push acceleration pedal of a vehicle with engine speed higher than about 1,500rpm in mid speed range. This is called "fuel-cut function" and almost every modern vehicle is equipped with this function. This is activated on downhill part of highways most often. Therefore the vehicle-exhausted CO_2 can be zero in this downhill part if the driver could recognize this part of highways and was informed the fuel-cut function. So the vehicle exhausted CO_2 can be reduced if drivers could recognize “CO_2 zero zone” where the fuel-cut function is activated.

This CO_2 zero zone is the downhill part of highways where the fuel-cut function can be activated. Drivers can reduce fuel consumption and exhausted CO_2 by using this CO_2 zero zone. We measured CO_2 emission with or without fuel-cut function in this study. And this CO_2 zero zone can be included in the policy of highway rehabilitation to reduce CO_2 emission by painting this part of highways with

different color. We compared CO_2 emission exhausted driving using fuel-cut function with cruising constant speed. And we proposed the selecting method of the optimum fuel-cut speed for minimum CO_2 emission in this study.

2. TEST PROCEDURE

We used NF Sonata(2,000cc, automatic transmission) for this test in the West coast highway of Korea. The certified fuel economy is 11.5km/L and CO_2 emission is 279.0g/km. In the first, we measured fuel economy and CO_2 emission by driving normally, i.e. just cruising with constant speed of 110km/h the highest speed of traffic regulation in this highway, and this data was measured from west Seoul toll gate to Mokpo toll gate(oneway trip mileage is about 336km) to set baseline fuel economy and CO_2 emission.

The fuel consumption was measured by using the electronic control method of injectors of gasoline engine. There are two wires for each injector as shown in figure 1.

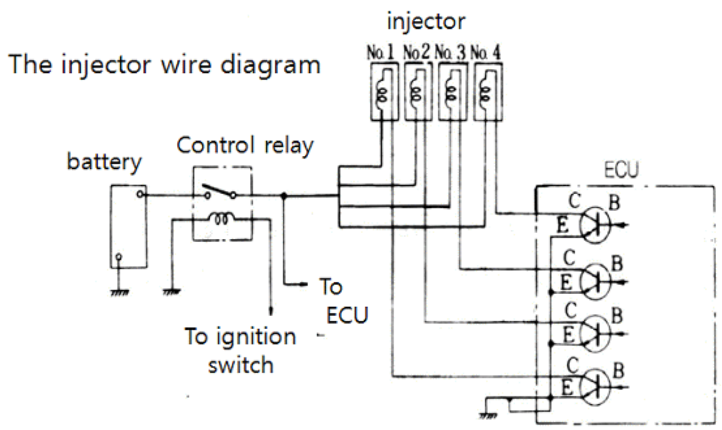

Figure 1. The injector wire diagram

One is for supplying electricity to injector from battery and the other is connected to ECU(Engine control unit). The injector is open when the wire connected to ECU is set to ground, i.e. zero voltage by ECU. In other words, injectors spray fuel when the voltage of wire connected to ECU is zero as shown figure 2.

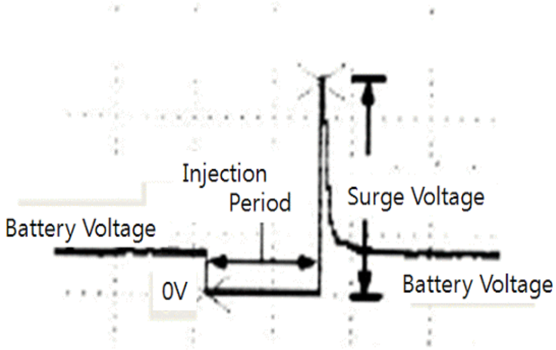

Figure 2. The electric signal of injector

We could fix the correction factor by measuring vehicle weight difference after driving the vehicle about 400km because the weight difference is due to the fuel consumption. By this method we can measure the fuel consumption without direct measuring fuel flow rate in and out from fuel pump which varies with fuel temperature. The work of connecting hose to/from fuel pump is very cumbersome and the flow meter is very expensive. We can avoid these problems by measuring just voltage signal of injectors. The driven mileage was measured by GPS sensor. As explained earlier we can calculate the fuel economy with these two data, i.e., fuel consumption and driven distance. And the CO_2 emission was calculated by multiplying the conversion factor of 2.31 with fuel economy.[1]

It's necessary to measure the altitude above sea level to determine downhill part of highway where the fuel-cut function can be activated. We used GPS sensor to measure this altitude data of road. We measured the fuel economy and CO_2 emission using fuel-cut function in the downhill part determined by this GPS altitude data after setting the baseline fuel economy and CO_2 emission. The vehicle was coasted down up to 100, 95 and 90km/h in the downhill parts for comparision. Table 1. Shows the test speed and methods.

Table 1 Test Description

Test Name	Cruising speed (km/h)	Decelerated speed (km/h)	Fuel-cut
Baseline	110	-	Not applied
A	110	100	Applied
B	110	95	Applied
C	110	90	Applied

3. TEST RESULTS

3-1. CO_2 emission of baseline

The baseline test result was measured without activating fuel-cut function just cruising constant

speed through the highway. The tests were performed for round trip and the result was shown in table 2.

Table 1. Test results of Baseline driving(without fuel-cut)

Direction	Fuel economy (km/L)	CO_2 emission (g/km)	Total CO_2 emission (kg)
To South(Seoul→Mokpo)	14.65	157.9	50.55
To North(Mokpo→Seoul)	13.57	170.1	54.46

It's good for fuel economy to drive to the South because the road declined slightly in that direction. The CO_2 emission in the sections between every interchange of the test highway was shown in table 3, and we'll call this table as CO_2 map in this paper.

Table 2 CO_2 emission of NF Sonata in west coast highway without fuel-cut function (just cruising in the speed of 110km/h)(CO_2 Map)

Section to the South		CO_2 (kg)	Section to the North		CO_2 (kg)
Seoul	Maesong	1.50	Mokpo	Muan	1.50
Maesong	Beabong	0.81	Muan	Hampyung	1.04
Beabong	Balan	1.94	Hampyung	YoungKwang	1.94
Balan	Pungtaek	2.13	YoungKwang	Gochang	2.33
Pyungtaek	Songak	2.15	Gochang	Sunwunsan	2.17
Songak	Dangzin	1.11	Sunwunsan	Julpo	1.11
Dangzin	Seosan	2.93	Julpo	Buan	2.66
Seosan	Haemee	1.64	Buan	Kimjae	1.78
Haemee	Hongsung	1.99	Kimjae	Donggunsan	2.54
Hongsung	Kwangchun	2.13	Donggunsan	Gunsan	2.17
Kwangchun	Daechun	3.05	Gunsan	Seochun	3.10
Daechun	Muchangpo	1.94	Seochun	Chungangdae	1.94
Muchangpo	Chungangdae	1.27	Chungangdae	Muchangpo	1.69
Chungangdae	Seochun	1.96	Muchangpo	Daechun	2.06

Seochun	Gunsan	2.40	Daechun	Kwangchun	2.59
Gunsan	Donggunsan	1.32	Kwangchun	Hongsung	1.41
Donggunsan	Kimjae	1.96	Hongsung	Haemee	2.29
Kimjae	Buan	2.17	Haemee	Seosan	2.36
Buan	Julpo	2.66	Seosan	Dangzin	2.86
Julpo	Sunwunsan	1.48	Dangzin	Songak	1.48
Sunwunsan	Gochang	1.43	Songak	Pyungtaek	1.50
Gochang	Youngkwang	2.96	Pyungtaek	Balan	3.10
Youngkwang	Hampyung	3.67	Balan	Beabong	4.13
Hampyung	Muan	1.48	Beabong	Maesong	1.87
Muan	Mokpo	2.47	Maesong	Seoul	2.84
Total		50.55	Total		54.46

3-2. Road ALTITUDE RESULTS

The altitude data was measured during the baseline test and the result is shown in figure 3. The altitude of the test road varies from 0 to 100m and we can determine the downhill part where the fuel-cut can be activated with these altitude data. The altitude of the road between Muchangpo and Chunjangdae is shown in figure 4. The altitude goes down from 1km to 3.6km continuously and the fuel-cut function can be used in this downhill part of 2.6km.

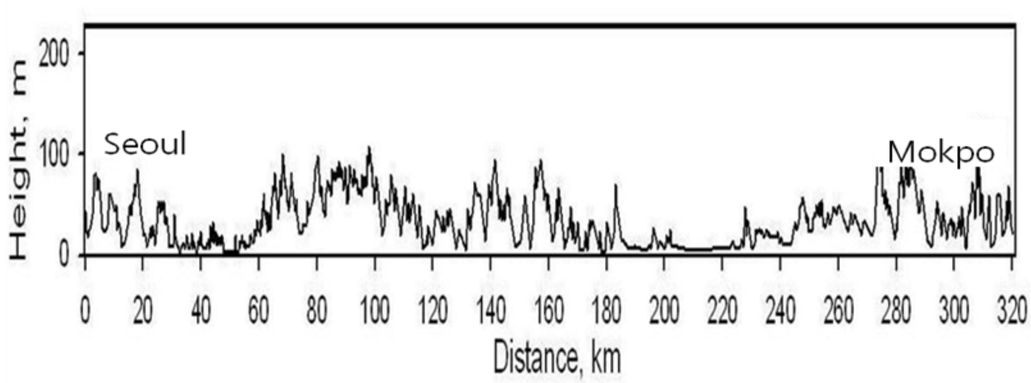

Figure 3. The altitude of test road

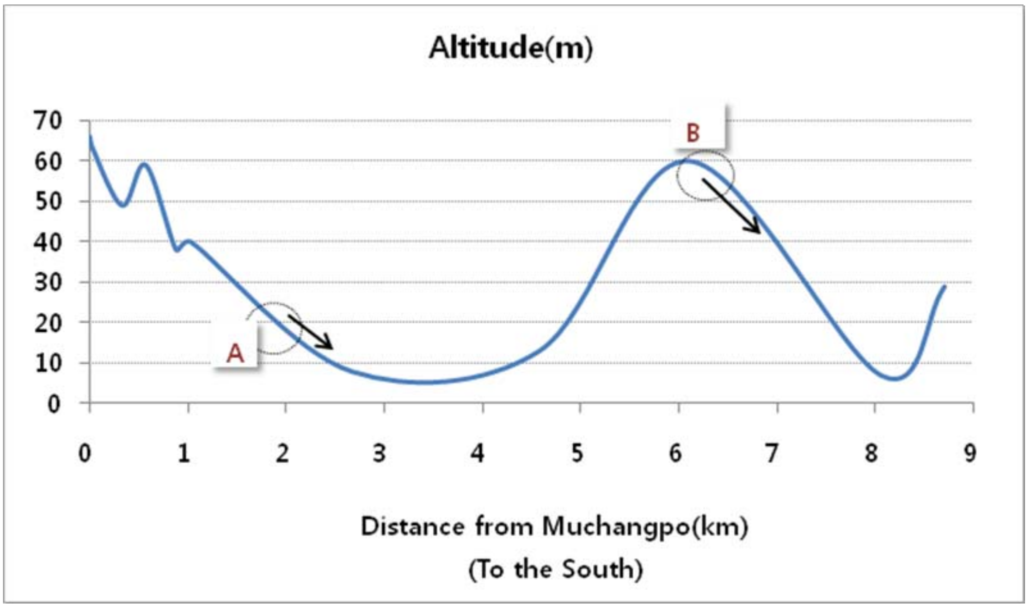

Figure 4. The alititude of the road between Muchangpo and Chunjangdae

3-3. Fuel Economy with different decelerated speed

We measured the fuel consumption in the downhill part of figure 4. with different decelerated speeds by fuel-cut driving to determine most economic decelerated speed. The speed reduces with driving fuel-cut(without pushing acceleration pedal) and then reaccelerated to the cruising speed of 110km/h. The fuel is not injected until the engine speed reaches to about 1800rpm, i.e. vehicle speed can be decelerated about 50~40km/h in the downhill part of highway. But it's dangerous to reduce the speed to 50km/h in the highway because there are interactions with other cars in the highway. [2] Therefore we decelerated the speed to 100, 95, 90km/h and then reaccelerate to the cruising speed of 110km/h to compare the fuel consumption. The longer the period of fuel-cut is, the better fuel economy is. And the fuel economy deteriorates as the fuel consumption for reacceleration increases. This comparison test was performed in the downhill parts of Figure 4. i.e. the section between Muchangpo and Chunjangdae at 2.0km(A) and 6.2km(B) to the South from Muchangpo. The road length of fuel-cut driving and the fuel consumption for reacceleration to the cruising speed of 110km/h was measured and the results are shown in Table 4.

The distance and fuel consumption was measured in two different roads, i.e. two sections to the South of 2km(section A) and 6.2km(section B) from Muchangpo. The fuel-cut distance becomes longer as the decelerated speed decreases. But the fuel consumption for reacceleration to the cruising speed of 110km/h increases as the decelerated speed is lowered. So we calculated the ratio of fuel-cut distance and fuel consumption for reacceleration and the results are shown in the last two rows of Table 4.

Table 4. The test results of fuel-cut distance
and fuel consumption for reacceleration

Test No.	#1	#2	#3	Remarks
Decelerated Speed	100km/h	95km/h	90km/h	
Driven Distance with fuel-cut(Distance)	100m	200m	250m	To the South of 2.0km from Muchangpo(section A)
	300m	400m	470m	To the South of 6.2km from Muchangpo(section B)
Fuel Consumption necessary to reaccelerated to the cruising speed of 110km/h(Fuel)	20.1ml	30.2ml	37.2ml	To the South of 2.0km from Muchangpo(section A)
	19.9ml	29.8ml	36.7ml	To the South of 2.0km from Muchangpo(section B)
Distance / Fuel (m/ml)	4.98	6.62	6.72	To the South of 2.0km from Muchangpo(section A)
	15.1	13.4	12.8	To the South of 6.2km from Muchangpo(section B)

The fuel economy is good for higher number of this ratio and test no.3(decelerated speed of 90km/h) for section A and test no.1(decelerated speed of 100km/h) for section B is the best. The fuel-cut distance is longer in section B but the reacceleration fuel consumption is almost same for both sections. It may be for the different roughness in these sections. Anyway the fuel economy can be improved by adjusting the decelerated speed. It’s better to lower the decelerated speed in the shorter fuel-cut distance section as section A. And it’s better to raise the decelerated speed in the longer fuel-cut distance section as section B. But the optimum decelerated speed cannot be calculated with these data and we’ll do more tests for this optimization in other study. We just selected 95km/h for decelerated speed for comparison of fuel economy with/without fuel-cut function. And it’s necessary to mention that the fuel economy can be improved more by optimizing the decelerated speed for different road conditions.[3]

3-4. Test Results with fuel-cut driving

The CO_2 emission from vehicle with activating the fuel-cut function in the downhill parts of the test highway is shown in Table 5. The total CO_2 emission is 48.44kg for driving to the South and 52.54kg to the North and the CO_2 emission reduced by 4.2% and 3.5% for each direction compared to the results driving without the fuel-cut function, i.e. just cruising in the speed of 110km/h. These reduction

rates could be higher if the decelerated speed were optimized for different road conditions.

Table 5. CO_2 emission of NF Sonata in west coast highway with fuel-cut function (decelerated to the speed of 95km/h)(CO_2 Map)

Section to the South		CO_2 (kg)	Section to the North		CO_2 (kg)
Seoul	Maesong	1.46	Mokpo	Muan	1.41
Maesong	Beabong	0.75	Muan	Hampyung	1.04
Beabong	Balan	1.86	Hampyung	YoungKwang	1.90
Balan	Pungtaek	2.00	YoungKwang	Gochang	2.29
Pyungtaek	Songak	2.15	Gochang	Sunwunsan	2.17
Songak	Dangzin	1.07	Sunwunsan	Julpo	1.04
Dangzin	Seosan	2.71	Julpo	Buan	2.44
Seosan	Haemee	1.58	Buan	Kimjae	1.68
Haemee	Hongsung	1.85	Kimjae	Donggunsan	2.38
Hongsung	Kwangchun	1.87	Donggunsan	Gunsan	2.00
Kwangchun	Daechun	2.79	Gunsan	Seochun	3.00
Daechun	Muchangpo	1.89	Seochun	Chungangdae	1.82
Muchangpo	Chungangdae	1.19	Chungangdae	Muchangpo	1.61
Chungangdae	Seochun	1.80	Muchangpo	Daechun	1.91
Seochun	Gunsan	2.36	Daechun	Kwangchun	2.59
Gunsan	Donggunsan	1.23	Kwangchun	Hongsung	1.34
Donggunsan	Kimjae	1.93	Hongsung	Haemee	2.24
Kimjae	Buan	2.17	Haemee	Seosan	2.36
Buan	Julpo	2.61	Seosan	Dangzin	2.86
Julpo	Sunwunsan	1.48	Dangzin	Songak	1.48
Sunwunsan	Gochang	1.40	Songak	Pyungtaek	1.43
Gochang	Youngkwang	2.91	Pyungtaek	Balan	3.05
Youngkwang	Hampyung	3.56	Balan	Beabong	3.94
Hampyung	Muan	1.44	Beabong	Maesong	1.87
Muan	Mokpo	2.38	Maesong	Seoul	2.69
Total(kg of CO_2)		48.44	Total(kg of CO_2)		52.54
Reduction Rate(%)		4.2	Reduction Rate(%)		3.5

The fuel-cut driven section and distance is summarized in the Table 6 and this table shows the zero CO_2 emission sections of the test road. We'll call the tables like Table 6 as "CO_2 zero zone map" in this study.

Table 6. The Distance driven with fuel-cut function(CO_2 zero zone map)

To The South(km) (Distance from Seoul)	Fuel-cut distance(km)	To The North(km) (Distance from Mokpo)	Fuel-cut distance(km)
4.2	0.3	5.3	0.3
10.7	0.3	13.4	0.3
18.5	0.3	15.4	0.3
18.8	0.3	39.2	0.6
28.3	0.4	47.2	0.6
30.9	0.5	68.4	0.3
61.8	0.3	73.4	0.3
65.8	0.5	75.8	0.2
68.4	0.4	123.5	0.2
72.8	0.4	136.3	0.4
81.6	0.4	157.4	0.4
89.9	0.3	165.8	0.5
91.5	0.3	168.7	0.4
101.3	0.4	174.7	0.3
105.8	0.5	180.1	0.5
108.2	0.4	191.2	0.3
110.8	0.3	199.4	0.3
113.4	0.3	210.2	0.4
115.8	0.4	214.8	0.3
119.0	0.4	216.6	0.2
126.2	0.4	222.2	0.3
127.1	0.3	223.7	0.3
129.4	0.3	228.7	0.3
141.7	0.3	236.6	0.3
147.7	0.2	240.3	0.3
151.9	0.4	241.4	0.2
156.6	0.3	248.9	0.4
160.0	0.4	251.9	0.3
164.2	0.4	255.4	0.5
175.3	0.3	258.5	0.5

182.8	0.6	289.5	0.3
195.9	0.2	294.9	0.3
229.2	0.3	312.0	0.2
248.0	0.2	317.0	0.5
265.9	0.3		
275.1	0.4		
289.1	0.4		
294.5	0.3		
308.8	0.3		
315.8	0.3		
Sum of fuel-cut distance to the South	14.0km	Sum of fuel-cut distance to the North	11.8km

The fuel-cut sections and distance is shown in Figure 5, and the dots in the right are the fuel-cut sections for driving to the South and left are to the North.

Figure 5. The fuel-cut section and distance of test highway(Seoul↔Mokpo)

The test results and comparison with/without fuel-cut function are summarized in Table 7. The CO_2 emission and fuel consumption reduced by 4% when driving 2000cc passenger car in the test highway with using fuel-cut function in about 40 sections of downhill part of which total length is about 14km. And there is room for more reduction of CO_2 emission if the decelerated speed is optimized with the conditions of road

Table 7. The summarization of test results

Item		To the South	To the North
CO_2 emission without fuel-cut		50.55kg	54.46kg
Fuel consumption without fuel-cut		21.88L	23.57L
Driven with Fuel-cut function	Number of fuel-cut activation	40 times	34 times
	Fuel-cut distance	14.0km	11.8km
	Reduced fuel consumption	0.91L	0.83L
	CO_2 emission	48.44kg	52.54kg
	Reduced CO_2 emission	2.11kg	1.92kg

4. CONCLUSION

We measured fuel consumption, CO_2 emission and road surface altitude for every IC driving 2000cc passenger car in the West coast highway in Korea and compared the fuel consumption and CO_2 emission with/without fuel-cut function in the downhill part of highway.

The fuel-cut function was activated in the downhill part by decelerating car speed to 95km/h and then reaccelerating to 110km/h. And we found the downhill part in the altitude data measured driving without fuel-cut function, i.e. just cruising in the speed of 110km/h..

The reduction rate of CO_2 emission is about 4% in the test highway with fuel-cut function and there are 40 sections where the fuel-cut function can be activated. This reduction of CO_2 emission can be maximized when the drivers know about the fuel-cut function and informed the downhill part of road by painting the sections with different color. The reduction rate can be raised by optimizing the decelerated speed for the road conditions.

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